Personal Portable Computers and the Curriculum

John Gardner

with contributions from

Hugh Morrison, Ruth Jarman, Clare Reilly and Helena McNally

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Contents

Teaching Issues

Organization Issues

Machine Locations
Charging Facilities in School
Powerpoints and Battery Charging
Furniture
Lighting
Classroom Resources
Use of Peripherals
Printing Pupils' Work
Printer Noise
Printer Speed

Software

Ease of Use
Variety of Software
Primer Guides

Hardware

Robustness, Durability
Reliability
Protective Carrier Bags
Portability
Warranty and Non-warranty Machine Problems
Supplier Support
Password Protected Hardware
Insurance
Screen Quality
Power Issues
Battery Issues
Disk Storage
Virus Protection
User Interface - Apple
User Interface - IBM compatibles
Memory

Some Conclusions

Personal Portable Computers and the Curriculum

Introduction

Personal Portable Computing

Portable computers, to all intents and purposes, are smaller versions of the common ‘desktop’ machines. Depending on their configuration they can be as powerful as the desktop machines but they have one major additional attribute. Instead of taking the work to the (desktop) computer, the lightness and design of the portables enables them to be carried to to the place of work - to the school desk, to the library, on the field trip and so on. Portable computers therefore hold out the promise of putting convenient and personalized computing power not just in our pupils’ hands but in our hands too.

The Project

Given the perceived potential of these little machines the Department of Education for Northern Ireland decided to investigate the practicalities of introducing them into the classroom. To this end, 235 machines[†] were placed in class sets in nine schools (one primary, one special education and seven secondary-level schools) for pupils and their teachers to own during a whole school year. The project was known as the PLAIT Project (Pupils’ Learning and Access to Information Technology). The range of classes included five co-ed groups and two each of single-sex boys and girls classes. Most of the classes were in the 12-14 years age range with one class of 14-15 year olds and one of 10-11 year olds. Although the pupils were free to use them in all of their lessons, the ‘focus’ classes were English, science and mathematics.

The Report

[†] For those interested in the hardware, the machines used in the project were the Research Machines Ltd NB201s, Toshiba T1000SEs, Apple Powerbook 100s and Tandy WP2s. The first two of these are IBM-compatible with 1Mb RAM and 1.44 Mb 3.5 inch disk drive while the Apple Powerbook is compatible with desktop Macintosh machines. The Tandy WP2 is a relatively simple machine with proprietary wordprocessing software in ROM.

In this report we will consider a variety of issues related to the use of portable computers in schools. In the first section we will consider the issues surrounding the use of computers in schools and in in the second we will report the findings of the PLAIT project in relation to the use and potential of the machines to contribute to the teaching of the main subjects. While the potential is amply evidenced it is important not to lose sight of the realities of using such high levels of technology in the classroom. The third section, therefore, sets out to report the practicalities, for schools and teachers alike, of one-to-one pupil usage of portable computers; it provides guidance on the pitfalls which await the unwary. The report throughout is derived from the observations of the research team, from tests and questionnaires completed by the pupils and from the experience of both the teachers and pupils as noted in diaries which they kept for the project.

Computing in Schools

As time goes on there seems no let up in the pressure on schools to integrate 'information technology', or IT as it is more usually known, into the curriculum. We are constantly exhorted to turn out our pupils as computer literate whizzkids - capable of exploiting the new technologies and mastering the intricacies of commerce and industry to transform us into a nation of great wealth and plenty. Heady stuff, and with it the expectation that we, the teachers, will deliver this technically literate and successful generation. There are, of course, some major problems standing in our way. Put plainly, these can be summarized in a number of simple questions: *What is this computer literacy we are charged with delivering? How can we deliver what most of us don't have ourselves?* and, once we know what it is, *how do we go about it? How can we provide all pupils with sufficient access to the necessary computing facilities?*

Why is Computing so Important in the Curriculum?

It won't be possible to answer these sorts of questions fully in this report (and given the pace of educational and technological change it may never be possible!) but the intention in writing it has been to shed light upon the issues, especially the classroom based issues, by sharing the experiences gleaned from the major project reported here.

Computing for Jobs

The pressure on schools and teachers to integrate information technology into our classrooms arises on a number of fronts. Firstly there is the perception, shared by government, employers, parents and indeed pupils alike, that 'doing computers' enhances the employability of pupils. Whether this is actually so is neither here nor there since the perception is sufficiently strong as to create a continuous and vociferous lobby for pupils to develop IT skills. The world of work appears to want an IT literate workforce so it seems it is up to us to produce pupils who are IT literate.

Motivation and Harmony

Secondly there is the view that the use of computers can contribute to higher pupil motivation, better quality of pupils' work output and generally more purposeful and harmonious learning environments. This is more substantively proven than the former perception and computers are widely accepted as being useful in supporting and enhancing aspects of classroom work.

Liberated Learning

Thirdly, there is the view that if computers can liberate pupils from, for example, the tedium of repetitive or long calculations or from the untidiness and confusion of handwritten drafting and redrafting, then their creative abilities can be given free rein and their learning can be improved. This is a less researched area and a number of conflicting views exist. On the one hand there are those who consider that conventional learning, as assessed by conventional techniques, is only marginally enhanced while on the other hand there are those who consider that computers introduce new styles of learning which cannot be assessed conventionally but which have no less importance in a pupil's education.

While these debates are of significant interest to schools, they tend, in the main, to take up the time of academics and to some extent policy makers. The primary concerns for schools remain constant and these reflect the practical issues related to teachers' confidence and competence in the use of computers, teachers' time and access to computers and the provision of sufficient resources for teachers and pupils to use.

What is Computer Literacy?

Computer literacy, or to put it in its broader form - IT literacy, is a many splendoured thing. It ranges across an exotic array of technologies which confront us day and daily: automatic bank tellers, barcode checkouts, broadcast information systems like Ceefax, satellite television, compact disk-based information banks or visual display systems and so on. All of these in some way or another enable us to store, process and communicate all types of information. At the heart of the matter lies the computer with its ability to process large amounts of information quickly and conveniently. This information is usually text or numbers but it can just as easily be images, video or sounds or indeed any combination of these - the so-called 'multi-media' information.

Literacy in these contexts means both a familiarity with the various forms of the technology and the ability to use the technology in a natural and competent manner;

for us to meet our own needs and where appropriate those of others. Current wisdom has it that in order to develop this literacy among our pupils we must provide them with a learning environment which enables them not just to *learn about* computers but also to *learn with*, and in some cases, *learn through* computers - a virtual immersion strategy!

Learning about Computers

Learning about computers is something we all have to do but it is important that we are clear about what we mean. For all but a tiny, specialist minority it is not important to know how computers work so much as how we use them (we all know how to use a television but do we know how it works?). Clearly, pupils need to know how to use computers in order to exploit them in their learning but learning the languages which a computer uses will not prove all that useful to most of our pupils.

Learning with Computers

Learning with computers is the most important member of the IT learning trio. Again, the received wisdom has it that if we use computers to support our pupils' learning, right across the curriculum, they will develop their own computer literacy automatically and will benefit from an enhanced educational environment. Thus, the argument goes, if pupils experience the uses of computers in all aspects of their schooling (including the administration of their schools) in addition to the many external manifestations of the technology, then they will leave compulsory education ready and able to confront and exploit the new technologies in any walk of life - IT will be a fully assimilated and natural feature of their development.

One up-and-coming context for learning with computers is 'interactive video', particularly in staff development. Interactive video disks are like compact disks in some superficial respects (eg. they are like 12 inch versions of compact disks) but they almost exclusively store moving video (with appropriate audio) sequences instead of the text, sound and still image mixes which the compact disks more usually contain.

There are a number of school-based interactive video training disks around including the SITC[†] Appraisal (for appraisers and appraisees) and Managing Time (for school

[†] Scottish Interactive Technology Centre, Moray House, Edinburgh and the Northern Ireland Centre for Learning Resources, Stranmillis Campus, Belfast.

principals) disks and the NICLR† QMS disks (dealing with training issues related to head of department responsibilities). Each of the training disks contains video sequences which present carefully scripted scenarios designed to cause the teacher to analyse and reflect upon the event or processes involved. Staff can choose when to study the materials and the usual follow-up is for the teachers who take the 'course' to meet regularly with their staff development coordinator or 'mentor' to develop and discuss the issues and ultimately to consolidate the training gains from the work.

Learning through Computers

Learning through computers is a more contentious area than the other two as it implies that the students' learning is mediated by the computer and not by a teacher - the machine is the facilitator of learning. Computer based learning - CBL (or computer assisted learning - CAL) of this type is attracting ever more interest, particularly in higher education where the number of students enrolling in universities and colleges is continuing to rise dramatically. With no increase in staffing many institutions are looking to CBL to provide the routine and foundation teaching, thereby releasing staff time for research and 'quality' student contact such as honours tutorials. CBL tends to take several forms. For example it might be a set of multiple choice questions for practice; a tutorial between the student and the machine with the machine leading the student through an information-explanation-assessment cycle; or an elaborate simulation of some event or process which the student has to study and make inference from.

Another form of new technology-based self-study is beginning to establish an important niche in resource based learning approaches to student learning. Multi-media databases can be designed to give students more control over their learning by enabling them to access large banks of resources on compact disks. Thus a student might browse through a database on a particular period of history, complete with facsimiles of primary sources (old maps, letters, manuscripts and so on) which they can collate and print straight off the compact disk. Many institutions, including schools, now offer the opportunity to search through compact disks containing several years' complete archives of all of the articles printed in the major newspapers, such as the Times or the Guardian, for articles on any chosen topic.

Aspects of both CBL and technology-based learning resources have been and are continuing to make an impact in schools. CBL packages are common throughout the curriculum but instead of replacing conventional teaching they tend to be used to support teaching and to enhance the study topic. Resource based learning approaches to pupil learning are also increasing with compact disk-based information sources now becoming common in school libraries.

From Familiarity to Competence

Familiarity is the first fence we all fall at. How many of us, when we first used a bank's automatic 'hole in the wall' teller, attempted to put the card in the wrong slot or upside-down or whatever? In the same vein, how many of us, even those of us who might describe ourselves as technically literate, can sit down at a new computer or a new wordprocessor with confidence that we will get going straightaway? Some would have it that technical familiarity and confidence is linked to a certain brashness which we as adults rarely have but which youngsters have in plenty. Our pupils will try everything with gay abandon until they get the machine to do what they want while we, in the same circumstances, grow red-faced with frustration and despair. We seek retreat and privacy for our inadequacies while our pupils simply charge on regardless!

Typing Inadequacy and 'Doing the Machine Harm'

For many of us it is difficult to acknowledge that we do not know as much as we would like to and this translates into a lack of confidence and a certain reluctance to become involved. We worry about our inability to type and the possibilities that we might damage the machine. These are not important concerns. Once we get past the 'hunt and peck' typing stage we usually become proficient two- and even one-finger typists (mind you, a typing course will not do any harm and will improve productivity!) and as for damaging the computer it's pretty hard to do. None of the thousands of learners we have dealt with have ever managed to do any harm!

Growth of Familiarity and Confidence

Once we do get the basic familiarity most of us can build our technical repertoire quite quickly - if we get the necessary time and access to the computers. The first level of familiarity is knowing the keys of the keyboard and their associated, normal functions. Keys like the SPACEBAR, the ENTER or RETURN key, the ESCAPE key and the DELETE or ERASE key find their place in our familiarity first, to be followed, as practice continues, by the CONTROL key, the TAB key, the CURSOR or ARROW keys and so on. 'Mice' can take a little longer as we practise and coordinate the hand movements and button-clicking while 'menus', which present us with a choice of useful shortcuts for getting the machine to do things, are usually soon appreciated.

Slowly but surely we begin to understand the processes of storing (saving) and retrieving (loading) our work, and we become confident in using our own set of perhaps favourite disks. Once we have used a program several times we can be reasonably confident that we 'know it' and it becomes relatively easy to integrate it into our teaching. There are, of course, the more sophisticated programs, such as wordprocessors, which may have many functions and features. Practice with these allows us to develop a minimum working competence to do most of the things we need, and our confidence reassures us that we will know how to use the documentation to solve any problems which may arise.

During these learning and practice sessions we begin to 'internalize' our understanding of the computer and its applications. We begin to appreciate that some processes and procedures are common and, in much the same way as we appreciate that most cars will have a steering wheel, four wheels and windscreen wipers, we also begin to expect most wordprocessors to have procedures for moving blocks of text, for checking spelling and for choosing alternative typefaces. However, we would usually not feel confident that we can face new wordprocessors or other unfamiliar pieces of software until this grasp of the concepts takes hold.

The Scope of Information Technology Literacy

In parallel with our pursuit of confidence and competence with computers we need to keep the scope of our needs in sight. In essence, information technology for most teachers and pupils means a core set of applications: **wordprocessors** (for communicating information usually in the form of text), **databases** (for storing and retrieving information usually in the form of text) and **spreadsheets** (for carrying out mathematical operations on numerical information).

Wordprocessors

The first of these, wordprocessors, are for everyone. The power and convenience of wordprocessor technology for communication of the written word goes more or less unchallenged today and most people, inside or outside of education and commerce, have some familiarity with the concepts if not the practice.

Databases

The concept of databases, as structured sets of information which we can search through, might not be commonly accepted in terms of their jargon name or their electronic forms but they are widely accepted in such forms as filing cabinet records or library catalogues. Once we are familiar with the means of 'interrogating' one electronic database, it is usually not that difficult to have a shot at a different one.

Spreadsheets

In so much as they are derived from their paper equivalents in conventional accounting, spreadsheets are most clearly attractive in numerate subjects such as mathematics and science. Spreadsheet concepts are probably the least familiar and perhaps the least useful for most people yet they are proving their worth in subjects as diverse as home economics (eg. in diet planning, home decoration planning and so on) and geography (eg. weather monitoring, field sampling measures and so on).

There are, of course, other applications of IT which have varying degrees of importance for education, including for example, electronic mail, interactive video and robotics, but wordprocessors, databases and spreadsheets are widely viewed as being of central importance. Let us now consider the framework within which these applications find their curricular rôle.

Information Technology in the Curriculum

Over the past ten years or so we have gradually refined our ideas about IT in the curriculum to the point where we can define five 'strands' of application or pupil learning activity. These may be worded differently in different parts of the UK but in essence they comprise the two general applications areas:

- §.. communicating information;
- §.. information handling;

the two specialist areas:

- §.. modelling;
- §.. measurement and control;

and, finally, a strand which covers the awareness of the *"uses of computers and their implications for society"* (SOED 1991a). Let us now examine what curricular processes these strands relate to.

Communicating Information

The first strand, *Communicating Information*, is primarily linked to wordprocessing and finds its curricular 'home' in the writing aspects of English. Various pupil activities are lined up under this strand including drafting and redrafting written tasks; revision, proof-reading and editing; writing for different audiences and writing in different styles (eg. narrative, discursive and formal). Extensions in the English classroom often include the use of 'desktop publishing' (DTP) software to create magazine-like publications and the use of electronic mail software to engage in remote national or even international communications with other pupils. Written forms of communication are obviously cross-curricular so wordprocessing for this strand of a pupil's IT literacy development can be addressed in many subjects.

Information Handling

The second strand, *Information Handling*, is also cross-curricular. It represents the processes which we use to gather and store information and the ways in which we structure and interrogate it. The most obvious application is the database but this may take many forms. There are databases which we use but do not contribute to, for example, a compact disk containing all of the year's stories from the Times or the Guardian newspapers or the broadcast materials in Ceefax on television. Alternatively pupils may use commonly available packages to create their own collections of information or databases, whether it be from field trips to examine life on the seashore or from surveys of pupils' likes and dislikes in music. Large collections of these can be stored on the computer where subsequent analysis can identify patterns, trends and so on.

Modelling and IT

Modelling is a specialist strand which relates primarily to science and mathematics contexts but there are many applications across the curriculum. At its simplest the 'modelling' strand covers the computer assisted learning (CAL) concept of 'simulations' where the computer simulates an event or process, usually by means of text but also, very often, by a combination of text, animated graphics and video. For example simulation packages are available which enable pupils to explore the events of the first world war or the management of domestic finances. Simulations - and their sometimes ‘fantastic’ derivatives, adventure games - are renowned for motivating pupils and stimulating discussion in, for example, English classes. *Modelling* proper, on the other hand, is the process by which pupils themselves attempt to ‘model’ a real-life event or process by making hypotheses and testing them out. For the most part such activities require some form of mathematical relationship between the elements of the model but it can be as relatively simple as the geometric rules which govern the creation of a shape, such as a triangle, using the special computer language, Logo.

Measurement and Control with IT

Measurement and Control aspects of information technology involve specialist activities and are also most commonly associated with science and technology. For example, pupils can monitor their science experiments, ‘capturing’ or ‘logging’ a variety of measures such as temperatures, light levels or humidity levels using special sensors connected to the computer. Once the computer has the data the pupils can process it to plot graphs, prepare tables and identify patterns and relationships among the data. In technology classes pupils can design and implement simple artefacts which are based on electronic parts, eg. a burglar alarm, and which can often involve ‘control’ in terms of the pupils instructing the computer to direct a small robotic device. Outside of science and technology there are opportunities for pupils to use computer based measurement facilities in, for example, geography fieldwork.

The Impact of IT on Society

The final strand of curricular information technology is different from the rest in so much as it does not involve a particular type of application. Rather it covers the need for pupils to appreciate how IT impacts on all aspects of society including banking and so on, telecommunications, satellite transmissions, stock control in shops, travel planning and so on. Social implications in terms of new patterns of working and new patterns of job opportunities are also high on this study agenda.

Learning from the Project

An important objective of the PLAIT project, was an investigation into the extent to which the portables can contribute to the delivery of the various school subjects. As mentioned above the main focus was on English, science and mathematics and in the next three sections we will explore what they could and could not do. It should be noted that, as outlined in the introductory section, the references to 'focus teachers' means those teachers who had a special responsibility to report on the use of the portables in a particular subject. 'Non-focus' teachers were teachers of the same class as the focus teacher but took them for different subjects.

Portables in the English Classroom

The project revealed a significantly high degree of usage of the portables in English, with the large majority of the activities involving wordprocessing. The focus teachers reported very positively on the impact of portables in English and their views were shared by the other non-focus teachers of English (ie. teachers of English in schools were the focus was science or mathematics). The results reported here, as in the case for science and mathematics, represent a synthesis of the work of all of the teachers and schools and of the observations of the research team.

IT and the English Curriculum

The project showed that the use of portable computers could address all of the IT-related dimensions of the English curriculum. Although the English curriculum for Scotland, for Northern Ireland and for England and Wales differ in terms of emphasis and detail, the common structure derives from the activities of reading, writing, talking and listening. In terms of IT there is perhaps less emphasis than in other curricula (cf. mathematics and science) but there is reasonable consensus on how IT can contribute to the English curriculum. This can be nicely summarized by the following extract from the SOED Guidelines on English Language 5-14:

> "The key uses of the microcomputer for language development are word processing, desk-top publishing, information handling, adventure games and simulations. All of these may stimulate thinking, reading, writing, listening and talking. Word processing improves the quality of pupils' writing by releasing them from problems of poor coordination in handwriting, and allows them to

> concentrate on the content, organization and editing of their own work. It creates a sense of audience and purpose and encourages the development of all the English language components through an active, naturally integrated process. As a medium for creativity, it can foster thinking and critical self-awareness and is a natural extension to drafting and redrafting. Since several pupils are able to plan and organize ideas directly on screen, word processing is also a catalyst for paired and group work. As text unfolds, it is easy for them to read and discuss content, structure, spelling and punctuation, to evaluate and learn the contribution of others." SOED 1991b

Desktop Publishing

The principal IT-related activities which were addressed by teachers during the project included designing the front page of a magazine using DTP (desktop publishing). In one class this had been carried out in the context of the creation of a school news-sheet while another class had experimented with letter formats and different layouts for poetry and newspaper texts. The classes produced displays which the teachers considered to be very satisfying work. One teacher reported that: *"This is perfect classroom work as audience awareness, presentation and language skills are all involved."* There was evidence that this desktop publishing activity was being closely linked with normal classroom reading of novels, poetry and so on.

Drafting and Re-Drafting

Pupils were able to plan, compose, revise, and redraft their writing on their portables, in discussion with teacher or peers. This was achieved successfully by all the primary and secondary-level pupils and there were positive comments from the teachers about the usefulness of this kind of activity. The pupils also showed independence in planning, revising and redrafting their writing on the portables. The primary class pupils took notes using the portable, organized the information, printed it and then shared it with other groups. In one secondary-level school the pupils analysed the letters of a group of primary children to Santa Claus and then organized this under a series of headings before constructing replies.

The facility of fast and efficient editing was appreciated by the teachers and pupils alike and was considered to have contributed to significant improvements in the pupils' output. The worry that personal machines might detract from collaborative work did not manifest itself in practice and the pupils happily cooperated and consulted with each other. The pupils regularly turned to their wordprocessor spell-checker and dictionary facilities and these had *"made a significant contribution to presentation of accurate work"* and were used *"with enthusiasm."* There were reports of an increased awareness of the need for accurate spelling among the pupils, and of a degree of independence on the part of the pupils in using spell-checkers without teacher intervention. The former was corroborated to some extent by the quantitative evidence from testing carried out in the project on pupils' writing. These indicated superior performance for the portable groups in comparison to the control groups (those without portables) in 'atomistic' analyses of their writing; and in particular the number of spelling errors per 100 words.

The pupils' awareness of the need for correct spelling was reinforced to the extent that they were more likely than before the introduction of the portables, to turn to conventional dictionaries for spelling checks. In addition, there were reports of an increased tendency among pupils to use dictionaries to check spellings where the spell-check may have failed, or where the pupil was unable to correctly select one of the options offered, due to their own lack of knowledge. The pupils' appreciation of the 'technical' aspects of writing was viewed as an ongoing development and the pupils were considered to show a *"better awareness of punctuation, paragraphing and formats than before and [could] appreciate these aspects of writing more clearly" ."*

As an aside, it is interesting to note also that the pupils began to use 'spell-check' as a verb and were quick to criticise wordprocessing software which did not have a spell-check facility.

Writing for Other Audiences

Writing which was designed to be attractive to other audiences, in terms of layout, illustration, style and so on, was accomplished using the portables in all of the schools. Most of the groups created materials for their school foyers and the work was described as having a high level of accuracy and good presentation. As mentioned above, one of the secondary level schools produced letters for primary school children but their work gained special recognition when an anthology of short stories which they created was published by the local authority. Another group sent letters to outside agencies while the primary group prepared illustrated short stories for the infant classes.

Curriculum Enhancement

In the case of the primary class, much more was felt to have been achieved in terms of meeting curriculum objectives than would have been possible without the portables. The pupils had worked in levels of writing competence which, according to the teacher concerned, was beyond what she would normally have expected of them. Pupils were considered to have increased their awareness of varieties of form, and had developed a greater sense of audience than they had had before the portables. The setting for writing had been extended beyond the teacher-pupil interaction to include a much wider audience. Pupils were more aware of the craft of writing and, in the words of one teacher, were *"more tuned-in as writers."*

The pupils were very skilled in wordprocessing, and could master all the techniques from simple 'keyboarding' to 'cut and paste', drafting and redrafting, using the spell-check and so on. Even the less able pupils were capable of producing a *"reasonable"* piece of work, which they would check for spelling before giving to their teacher for reading. *"I doubt if any class in any primary school in the Province could handle this work as well as they can ... I feel that the work they do drafting and redrafting on the computer has begun to transfer into their handwritten work. I have begun to see better punctuation and paragraphing..."* This observation was in fact borne out by the tests of writing ability which were conducted during the project.

Pupils with Special Needs

In the special needs environment, the access to a personal portable had a very positive impact as a personal writing tool. Pupils with very poor handwriting skills were able to achieve a great deal because their writing was more presentable. The teacher felt that using the portables had enabled her to overcome this hurdle and begin tackling writing skills in a more focused manner. Drafting and redrafting was refined over time with the result that the pupils were eventually able to produce a finalized piece of work in perhaps only two drafts instead of four. They had become much more aware of the need for thinking about writing before they write, in terms of planning a structure, contents, awareness of audience and so on. Apart from these skill-based considerations, an increased confidence on the part of the pupils as writers was reported.

Collaborative Working

Collaborative pair and group work was used widely with the portables. Activities included pupils producing a collective piece of work and pupils reading or listening to each other's work. The teachers reported an increase in pupils' willingness to allow their work to become public, and an increase in self esteem and self confidence. The individualized ownership of the machines did not appear to give rise to trends against collaborative/cooperative writing.

Assessment Issues

The teachers reported that assessment was successfully carried out using the portables in the English classroom. Assessment of layout, paragraphing, presentation of writing and so on for wordprocessed work was considered to be relatively convenient while assessment embracing content, appropriateness of language for context, awareness of audience, vocabulary and so on was facilitated by the relatively easy-to-read typescript. Access to the portable and printing facilities enabled the teachers to keep evidence of noteworthy pupil output much more easily than if they were relying on work which had been carried out on a computer network. The work was produced much more quickly on the portable, and the teachers were able to build up files of coursework for the pupils with copies conveniently retained by the pupils.

Impact on Writing

The work produced by the pupils was felt to be more developed, more imaginative and longer than would normally be the case for a handwritten task of the same nature. However, the transfer to general writing skills was tested empirically using writing tasks which enabled comparison between the portable groups and the control groups. Although they were statistically non-significant, the results indicated that on quality and creativity measures the portable pupils did not fare as well in contrast to the objective measures of spellings and so on mentioned above. The issue of length of work needs to be qualified since most of the pupils could not type as fast as they could write by hand. While the portables may have motivated pupils to create longer pieces of work over an extended period of time, in a fixed time they would probably have produced less. Some of the pupils were very much hampered by their lack of typing skills. The pupils' oral work showed an improved confidence and the pupils were more expressive and capable of contributing to discussions.

The English teacher in the special school reported a definite improvement in the standard of coursework with the presentation and content of their work having improved considerably. In addition the morale of the pupils concerned was reported to have been high.

Use of Additional Resources

In the case of the English focus teachers, none declared themselves as IT-competent before the portables project. They felt they had had to work hard to come to terms with the hardware and software, and on planning the integration of the portable into the curriculum. There was a general feeling among them that a fairly high level of training and support would be necessary for a proper and effective integration of the portable usage in their lessons. One teacher used the local education authority technician regularly in her classroom for technical support. Others relied heavily on school technicians or IT co-ordinators to help them over the initial hurdles of machine familiarity, printing and so on.

'Keyboarding' Skills

Only one of the schools had a policy of teaching 'typing' in first form and the pupils reported that this was helpful when using the portable. Some pupils said they would like keyboard skills to be taught and others reported that they still preferred to take notes using pen and paper rather than the portable, since they found it less time-consuming. However, most pupils seemed capable of typing at a reasonable pace after some practice.

Portables in the Science Laboratory

The bulk of this work derived from the experiences, both observed and reported, of the schools in which the portables were used in science. Without reservation, the teachers involved considered that the portables enabled them to address all of the IT curricular dimensions in science.

Wordprocessing in Science

Predictably perhaps, the science teachers in the project chose to start with wordprocessing as a means of familiarizing the pupils with their machines and as a means of addressing the curricular needs of *Communicating Information* in science. The most obvious example was pupils using their computers to make a written record of their experimental work. At first their reports were often disjointed and their progress slow. With editing so easy, however, their teachers were able to intervene to suggest improvements and, as a result, they noted a rapid advance in terms of organization and layout.

Although the process remained slower than handwriting, the quality of the work was high and the pupils showed pride and pleasure in the product. In one school, the pupils were already quite proficient in wordprocessing as a result of their work in timetabled IT classes in the previous year. They used their personal computers to draw up plans for investigations and problem solving activities. Significantly, when asked if it would not be easier to use pencil and paper, one girl insisted she would rather use the computer. *"It makes me feel more scientific"* she explained. This motivation was found to persist throughout the project.

The pupils also used their personal computers to wordprocess written assignments on topics as diverse as space exploration and pollution. Again, work of quality was produced.

Pupils' Autonomous Working

Although there were occasions when the teachers issued explicit instructions that the pupils should wordprocess their work, the pupils did very often exercise considerable autonomy. For the most part they themselves chose how they wished to present their written reports and there were instances of the pupils having typed up science information which had not been required or requested by their teacher. Thus, one primary school pupil wrote in his diary *"I also added some of my own work to my computer, a list of the elements (substances that cannot be broken down into anything) eg. Au gold, Sn tin, Ne neon, etc etc."*

In as much as they tutored each other in the technical use of the machines, the pupils worked collaboratively. Individuals also demonstrated a degree of autonomy in the use of their machines, as exemplified in a small scale study with one of the classes. The pupils themselves were invited to pose problems in science and to plan, perform and report their own practical investigations to solve the problems. This provided the teacher with an opportunity to explore the extent to which the pupils, when working independently, exploited their computers in their work. The outcomes of the study were encouraging as all of the pupils used the portables in at least one aspect of their investigations. Wordprocessing, predictably, was the most popular application but many pupils also availed of spreadsheets to present their finding in the form of tables and graphs. A few used sensors to collect experimental data but, curiously perhaps, none used databases. When the applications were used they were almost always used appropriately and, in the context of individual investigations, the ratio of actual use to potential use was high.

Class Sets of Portables

Some of the teachers felt that having a class set of, say, ten machines in their laboratory would be a particularly useful arrangement in place of having one with each pupil. In effect most of the classes had only a limited set of sensor and other peripheral equipment so it was never possible to have all of the pupils using sensors at the one time. Group working with a smaller set of machines in operation was found to be quite acceptable for experimental data-logging work.

Using Databases in Science

Pupils also undertook a range of data handling activities (ie. addressing the *Information Handling* strand) using their portables. In the primary class the pupils extended their use of computers to the preparation of databases in support of a cross-curricular project on ‘Energy’. In the secondary classes, pupils created and interrogated databases relating to topics such as the periodic table, the nutrient components of food and the Earth in space.

Using Spreadsheets in Science

The pupils used spreadsheets on their portables to present the results of their investigations in graphical form. However, as one teacher observed: *“It's almost too easy to draw a graph on screen!”* The teachers were anxious that their pupils should not lose their personal graph drawing skills. This is an important issue. IT competences should complement rather than replace those key skills which pupils require in science and in every day life. At the end of the project, when the pupils’ performance in a science test was analysed, the results suggested, however, that there was no detriment to the pupils data-handling skills. The test itself had an emphasis on graphical representation items and was confirmed to be highly reliable. All of the portables classes showed superior gains in comparison to the control groups (matched classes who did not have portables) but it should be stressed that statistically significant differences were found for only one group (a group with the highest ability pupils).

Modelling and Simulations

The least work was undertaken in the area of *Modelling*. Using spreadsheets, one teacher did attempt mathematical modelling with data derived from an experimental investigation on the stretching of springs. Albeit with some effort, the class was able to arrive at Hooke's Law. Scientific simulations, on the other hand, were not used. This does not reflect a lack of awareness on the part of teachers of the value of such activities, nor a lack of ability to incorporate them into their programmes. Rather, it was a resource issue. The simulation software at the teachers' disposal was designed for use on BBC computers and no suitable software was available to them for the primarily IBM-compatible portables.

Measurement and Control

On the other hand, when interfaced with sensors, the data capture capability of the portables proved to be particularly productive in supporting scientific investigations and addressing the *Measurement and Control* strand of IT in the curriculum. Interestingly, this application attracted the most favourable comments from the science teachers. Indeed, it was suggested: *"If portables did nothing else, they would be worth it for their data logging facilities"* and *"Given more sensors, the sky's the limit."* Sensors were used in physics, chemistry and biology investigations and the teachers commented on how they were looking forward to extending this type of work in the future. The speed with which the pupils became proficient in the use of sensors and their associated software and hardware was considered to be impressive.

Significantly, too, it was in this area of application that the pupils showed the greatest readiness to propose their own lines of enquiry. The pupils in one class, for example, while studying the effects of acids on metals, learned that heat was given out during the reaction. They subsequently used their sensors to investigate the rise in temperature - an activity which would not normally be attempted by second form (12 year old) pupils. In another class, the pupils were encouraged to ask their own questions, to formulate simple hypotheses and to test their ideas by investigation. It was interesting to note that a number of the pupils chose to use sensors in their explorations.

Remote logging is so easy with the portables that, in one school, the machines were used by other science classes in preference to the use of the school's bank of BBCs. Furthermore, a senior student used a portable in a practical project which won a commendation in the Intermediate Biological and Ecological Section of the Aer Lingus Young Scientist Competition. Full advantage was not taken, however, of the flexibility afforded by portables in respect of data capture beyond the confines of the classroom. Only light, temperature and position sensors were available to the schools during the project and it is considered that the provision of, for example, pH and oxygen sensors would allow more comprehensive environmental monitoring.

Although much use was made of the measurement capability of the machines, suitable hardware and software was not available in the schools to enable them to employ the portables in control contexts.

Evaluating the Potential of IT

A major aim of IT in the curriculum is that pupils should come to an awareness of a range of applications of IT and an appreciation of its potential significance in their own work and in the work of others. Beyond doubt, the virtually unhindered access of individual pupils to personal computers makes an major contribution to the realization of this intention. On occasions, such 'awareness' was explicitly taught by the science teachers. In one class, pupils plotted a graph, by hand first and then on their portables, and subsequently discussed the effectiveness of IT in meeting their needs in this specific situation. More important, however, was the hidden curriculum of the personal computer. The pupils were continually confronted with the advantages and the disadvantages, the strengths and the weaknesses of the new technology. This was an experience not usually gained in traditional approaches to IT provision.

Assessment

Continuing developments in assessment practice in some cases request and in other cases require that teachers assess their pupils' attainment in IT-related science issues in a much more systematic way than would have previously been the case. This calls firstly for the identification of appropriate opportunities for pupils to deploy, and hence develop, a range of IT skills; and secondly it calls for opportunities for teachers to observe their pupils exercising these skills in a range of contexts. These dual demands represent a considerable challenge and the science teachers felt that a strength of the provision of personal computers was the ability to meet this challenge. The use of the portables allowed plenty of opportunities for the observation of pupils at work and plenty of scope for dialogue with individual pupils about that work. This may not make assessment simple, but it does make it possible and the teachers felt confident that they would be able to comment on aspects of individual pupils' performances in terms of IT in science or in IT *per se*, if that was required.

Despite some early interest, no attempt was made to use the portables for holding and presenting drill or test items in science, nor for storing pupils' self-assessment schedules.

Lesson Planning and Preparation

Prior to the project, the science teachers in the schools with a focus on portables in science were already using IT to support their work with pupils. However, because of their involvement in the project, they did feel themselves under additional pressure to actively seek out opportunities to incorporate the use of the portables into their lesson plans. In one sense this was made easier because the inception of the project coincided with the introduction of the new science programme of study with the consequence that schemes of work were quite fluid. In another sense this was made more difficult because the science departments were also dealing with a new curriculum, new approaches to assessment and, in one case, a general inspection!

The use of the portables added to the burden of preparation for teaching and learning. It was clear from the beginning that time is required to try out the procedures on the machines in advance of the lessons. Time is also required to prepare lesson resources, such as step by step instructions to support the pupils as they work with their computers.

In addition to the need to have time to prepare materials and activities it should be noted that the teachers reported time lags of up to three weeks against the normal schedule of teaching. This was largely due to initial problems with familiarity (teachers and pupils) and was therefore reduced by the end of the school year. However the use of portables in the classroom did introduce extra calls on lesson time and the effect was never removed completely.

Teaching and Learning Styles

The science teachers reported that the use of portables, by pupils, had not dramatically altered their own approach to classroom management nor had it changed their teaching style. It was suggested that, because science lessons are lengthy and involve practical work, computers are less intrusive than they may be in other subjects areas. For example, in science classes there is routinely much more flexibility in terms of time and movement for pupils and so activities such as typing and printing are more readily accommodated in the course of the lesson. Nevertheless, some aspects of the teaching styles were found to be different. The teachers reported, and indeed observations carried out by the research team confirmed, that they had had to become more mobile in the classroom and that they interacted more with individual pupils. These extra interactions, however, were mostly machine query or problem oriented.

The project demonstrated that an IT rich environment, such as is afforded by the provision of portables, can assist substantially in the delivery of the science curriculum. One teacher summarized it thus: *"I think it is possible to meet all the requirements of the [Northern Ireland] curriculum using the portables. Indeed I do not think it is possible without them. Certainly, it would be very difficult."*

It was the view of the science teachers that the possession of portables had proved a very positive learning experience for those pupils participating in the project. They had become confident and competent users of the technology and the process had extended and enriched their experiences in science. Many had gained a sense of achievement through the standards of presentation possible with wordprocessing and through the effectiveness of using the portables for gathering, handling and communicating information in science classrooms. Success had bred success and this study showed that portable computers can effectively fulfil the IT-related dimensions of the science curriculum and can enliven and enrich the pupils' learning experiences.

Portables in the Mathematics Classroom

IT in the Mathematics Curriculum

The mathematics curricula in the UK (ie. the separate treatments in Scotland, England and Wales, and Northern Ireland) have more or less the same elements for pupil learning; differing mainly in presentation and perhaps a little in emphasis. They divide naturally into groupings which are variously described as attainment outcomes or targets. For our purposes we will use the following generic versions of these curricular elements beginning with the target for pupil learning which is related to mathematical *process*:

§.. problem solving and enquiry

and the targets related to the *content* of mathematics in terms of concepts, facts and techniques:

§.. data or information handling
§.. number and measurement (including patterns, sequences, functions and equations)
§.. shape, space and movement

The process target is used by teachers to assess the problem-solving abilities of pupils ie. their skills in planning mathematical strategy, conjecturing, generalizing and communicating mathematical ideas effectively. The content targets are used to gauge mathematical knowledge.

Information and Data Handling

The following aspects of the 'information and data handling' targets were addressed directly in the portables classrooms in the project:

§.. interrogating data in a computer database;
§.. inserting and interrogating data in a computer database and drawing valid conclusions.

In a number of cases this type of activity was spontaneously undertaken by the pupils on their own data (eg. creating a database of a compact disk music collection).

§.. producing various forms of representations of data;

The portables proved useful in augmenting pencil and paper exercises on pie charts, bar charts, line graphs and so on. They were particularly useful in enabling the pupils to quickly and conveniently investigate the differences in data representation and interpretation in the various formats. There was also evidence of the skills being exploited to create bar graphs in, for example, both science and home economics classes.

Number and Measurement

In the 'number and measurement' target area there were routine examples of the pupils using the calculator facility on their portables (in one case the class found and began using this facility independent of the teacher who had not realized it existed) and also spreadsheets to look at interest accrual on money saved or borrowed over time (a number of the schools used a spreadsheet to investigate and compare simple and compound interest). Practice on changing units was also easily accomplished on the portables. Independent working was again in evidence with, for example, one pupil maintaining his own bank account on a personal spreadsheet.

In view of the age range of the majority of the pupils, it was not possible to gauge the contribution which the portables could make to higher level aspects such as using spreadsheets to investigate the feasibility of a mini-enterprise or business project but the teachers could anticipate no difficulty in using the portables to deliver and assess such work.

Shape, Space and Movement

The following aspects of the 'shape, space and movement' targets were also addressed directly using a Logo package on the portables:

- investigating position in terms of angle and distance;
- devising instructions to produce desired shapes and paths.

These were exemplified by drawing equilateral and isosceles triangles and extending to the drawing and calculation of angles of regular pentagons and hexagons. Understanding Pythagoras' Theorem was also considered to be assisted through the use of the portables. Logo was used to plot coordinates, to investigate angles of turning, to estimate distance and to produce various shapes and repetitive patterns eg. a square followed by a rotation of 3.6°, repeated 100 times.

- generating and transforming 2-D shapes;

Transformations were accomplished using repeat procedures with constant change of angle and moves to different coordinates on the screen.

Access to Spreadsheets

Spreadsheets offer a powerful medium for pupils to tackle the various ‘trial and improvement’ methods which form the basis of solving equations by iteration while portable access allows the teacher to illustrate the method conveniently with each pupil. While new formulae require to be memorized as new equation types are encountered, the iterative method applies for **all** equations making portable access invaluable.

For mini-enterprise or business project work, the access to computing afforded by portables permits pupils to use full year profit/loss and cash flow spreadsheets to perform feasibility studies. A lower level of access, such as that afforded by network booking, would militate against carrying out a study which accurately reflected the ‘real thing’. A class equipped with portable computers can follow the formation of the company from the initial market research to the calculation of the overdraft which will secure the well-being of the business. In this manner a superficial exposure to *Modelling* is quickly converted, through portable access, to a detailed insight into the applications of mathematics to business.

Graphs arise almost daily in the mathematics classroom and they play an important rôle in the mathematics curriculum and all mathematics curricula suggest that pupils should be able to generate various types of graphs on a computer (or a calculator) and interpret them. Portable access to graph plotting software facilitates the checking of pencil-and-paper work but more importantly it empowers the pupil to explore. A pupil is more likely to internalize the concepts of gradient and intercept, for example, if asked to explore the family of curves governed by the equation $y = mx + c$ for various values of m and c. Moving on from there, the computer based graph plotting facility allows the pupil to ask and respond to *“What would happen if?...”* questions. For example: *“Given the graph of y = sin(x), what will the graph y = sin(x/2) look like?”*

Access to Logo

Logo is a popular computer language for mathematics teaching and learning and it has many claims and counter-claims about its classroom worth. For example, Papert's claims for Logo, in his book Mindstorms (1980), have been the subject of many research studies. However Logo does not make a significant contribution to the mathematical content target: 'shape, space and movement' since polar coordinates and transformation geometry do not arise frequently in the mathematics classroom.

Papert asserted that children acquire problem-solving skills essential to their mathematical development through investigating in the medium of the Logo programming language. It is considered that children, who learn to program in Logo, improve in logical thinking, become better problem-solvers, acquire enhanced abilities to locate and correct errors in mathematical reasoning, and recognize more readily that there may be many strategies for solving a problem. Logo may therefore make a powerful contribution to the process target in mathematics. The fact that in past studies children have failed to acquire strong transferable problem-solving skills from Logo might be due to insufficient time having been available for the pupils to master it. With the high level of access to a Logo environment which portables can offer, they are therefore more likely to provide a unique contribution to the development of the problem-solving skills of children.

Access to Database Software

All mathematics curricula acknowledge the value for pupils of collecting, organizing and graphing real-life data but most teachers of mathematics recognize the time-consuming nature of such valuable learning. The portable computer can make a contribution in that the tedium of assigning data to intervals, tallying and constructing bar charts can be removed, enabling the pupil to concentrate on the higher level skill of interpretation of the summarized data. Statistics and probability have a central place in the curriculum and the portable computer can also provide the opportunity for convenient exploration of real-life data.

Access to Drill Software

All mathematics curricula also require that pupils have skills in mental arithmetic and regular access to drill and practice software (usually in the form of multiple choice or true/false type questions) significantly enhances number skills. A survey of the research literature on the computer assisted learning of number skills, carried out by Roblyer in 1985, shows that pupils with regular access to drill software demonstrate significant gains over pupils using more traditional methods for learning number facts. The levels of access necessary to ensure long term improvements are, however, probably only achievable with the high degree of personal access to computers that is offered by portables.

Pupils' Autonomous Working

Overall there was much evidence of pupils using the machines independently in mathematics - with database and spreadsheet work featuring prominently. The pupils seemed to learn very quickly, including relatively complex activities in Logo, and the extent of peer-support and collaborative learning moved one teacher to say: *"I'm amazed .. at the spontaneity of work produced right across the spectrum .. at the exchange of skills and information .. I could abandon the class and they could teach each other!"*

Teaching with Portables

This section reports on issues related to the day-to-day teaching with portables and covers implications for teachers and school and classroom organization.

Implications for Teachers

All of the teachers reported having to spend a great deal of time familiarizing themselves with the machines before they felt confident to plan and conduct purposeful lessons. The Microsoft Works tutorial ‘Learn Works’ was favourably commented upon in this context. A degree of help and support from experienced colleagues and particularly from pupils was reported. A number of the schools had IT technicians, some full-time and some shared for various periods with other non-project schools, and their support was considered invaluable. All of the teachers considered their own IT literacy to have developed significantly with consequent development of their own morale and confidence. They also considered the portables to have afforded opportunities for innovative teaching approaches and looked forward to a more effective use of the technology in the next year.

INSET vs Portables for Teachers

There was consensus among the teachers that in-service training (INSET) remained a high priority for facilitating the successful integration of IT in teaching. However, experience in the project had convinced the teachers that a particularly effective way would be for all teachers to have a personal machine, preferably a portable for transit between home and school. It was felt that the high level of personal access had enabled the teachers to optimize their own familiarization with the machines and their integration of IT into their teaching schemes. During the project, some of the non-focus teachers, who were teaching the pupils who had portables, complained that they also needed portable machines for themselves in order to prepare lessons for the class.

A Lag in the Teaching Schedule

For the first month a considerable proportion of time in lessons was taken up with computer-related activity (either familiarization issues or technical problems) and at least six of the teachers considered their class to be behind in the teaching schedule. For most classes the majority of the lag was considered to have been ‘caught up’ by the middle of the second term but the science and mathematics teachers still considered that their classes continued to lag behind other classes in the year group owing to the amount of lesson time being spent on the computers.

Length of Lesson

Lesson periods of at least one hour duration (eg. a double 35-40 minute period) were generally considered to be the minimum for a portables-based lesson although the harddisk machines (the Apple Powerbook 100s) were frequently and successfully used in single 35 minute periods. In the primary school it was usual to give over an entire morning or afternoon to using the machines. In the case of one of the secondary-level schools, the teacher's original single-period time-table had been changed to allow double-periods. The prime reason given for requiring longer periods was the time needed at the start of a lesson for taking out and starting up the portables and at the end for saving files and shutting the machines down. At the beginning of the project there was a significant time consumption (anything up to 20 minutes to get all pupils and all machines ready with perhaps ten minutes at the end to have all files saved properly and so on) but by the end of the project the start-up timing was down to a maximum of five minutes with the time needed at the end varying from one to five minutes depending on the type of activity. However, at least two of the teachers reported that on occasions the start-up and shut-down processes could be much longer. One method of saving a significant proportion of lesson time was to have the pupils carry out preparatory work (eg. data input in a database file) at home.

Lesson Planning and Pacing

In the initial stages of the project the teachers reported, in their post-lesson diary notes, that they were over-ambitious in their lesson planning and had not mastered the pacing of portable-based lessons. As time went on, and the teachers and pupils became more adept with the technology, this problem was much reduced. Some lessons, however, continued to overrun with pupils having to finish work at home or carry it over to subsequent lessons. Having to deal with technical problems would appear to be a persistent cause of some lessons not being completed. In the majority of cases the portables were planned into a series of lessons rather than one-off activities.

Technical Support Issues

Technical Problems and Disruption to Teaching

All of the teachers commented on the amount of time which they had to spend resolving technical problems. On average, at least one battery would go ‘flat’ per lesson and the teachers considered that the disruption to teaching (to sort out the problem) reached an intolerable level when more than three such events happened per lesson. Early in the project, disruptions due to battery and disk problems were accumulative, amounting in some cases to 30% of the lesson time. Clearly these can seriously disturb the lesson delivery.

A ‘New’ Technical Support Rôle

Teachers with portables in their classes had to adopt a new rôle: that of a supportive ‘technician’ dealing with software-related problems (eg. wordprocessor or database functions) or directly with hardware problems (especially those related to batteries and disks). While it could be argued, perhaps, that science teachers would at least be familiar with the concept of providing ‘technical’ support to pupils in a lesson (the obvious example being experiments), it is clear that such a rôle is not familiar to mathematics or English teachers and is unlikely to be familiar or indeed welcome to the majority of teachers.

Need for In-situ Technical Support

All of the teachers considered that *in situ* classroom support on technical issues would be needed to retain the fluency of normal teaching and some alluded favourably to the ‘network’ room situation where the setting up of the hardware and software was automated and dealing with technical problems was someone else’s responsibility.

Decreasing Impact of Problems

Set against the case being made for *in situ* technical support there was evidence that by midway through the second term the problems of classroom management and organization had reduced as the pupils and teachers became more adept at the various technical processes (use of wordprocessor, printer and so on) and the early novelty aspects gave way to a more purposeful approach to use of the portables. The teachers reported being much more confident in the face of problems which now fell into familiar categories. Problems which could be dealt with quickly were tackled while those recognized as being more difficult were set aside and not allowed to take up lesson time. Although the incidence of all such problems (simple and complex) was much reduced it was clear that they would always exist and therefore would cause some level of disruption both to the teaching flow and to the work of the pupils concerned.

Network vs Portables: Continuity of Working

While at present the provision of a network or networks of computers is the most frequently encountered model for providing access to computing in schools, the project has shown that the portables have four principle advantages over networks. Firstly, the network usually has to be 'booked' in advance by the teacher, an arrangement whereby the lesson moves from its normal setting to the computer network; perhaps for the same weekly period or periods for several weeks. A typical series of lessons to illustrate the application of databases to statistics might begin with instruction on the fields and contents of the selected datafiles. However, a substantial portion of the second lesson will often have to be devoted to revising the information given during the previous week's lesson, on fields and datafiles, before further teaching is possible. Portable computers allow for much more continuity in the lessons and therefore remove the 'fit and start' aspects associated with intermittent network access.

Network vs Portables: Practice at Home

Secondly, the teacher may set exercises where pupils practise basic information technology skills, such as an elementary database interrogation, for homework. Pupils are more likely to experiment at length in their homes and more likely to return to the classroom the following day with a clear understanding of simple interrogation procedures. Portable computers therefore offer the teacher the opportunity to begin the next lesson on, for example, more advanced interrogation methods, secure in the knowledge that all pupils will be at the same stage of development.

Network vs Portables: Integration in the Subject Curriculum

Thirdly, the use of portable computers can assist the integration of information technology into the curriculum - one of the central aims of modern curriculum design. The physical move to the computer network may serve to distance information technology from the subject it is being used in since the network room is unlikely to have the same range of appropriate and accessible resources. The use of portable computers in the context of each subject's classroom emphasizes that information technology provides powerful tools for these subjects.

Network vs Portables: Accessibility and Convenience

Lastly, teacher autonomy is much enhanced through portable access. Teachers often have to negotiate network time well in advance and frequently find themselves rushing a topic or truncating a series of lessons in order to take full advantage of the sessions offered them by the network manager. Portable computers allow the teacher to use information technology to support their teaching when and where they feel it is warranted. For example, in order to illustrate the properties of polygons in mathematics, the teacher may introduce the topic using Logo on the portable, then present some geometric theory using traditional pen-and-paper activities and continue the topic by returning to the computer-based teaching. In addition there are many unplanned teaching opportunities in every subject, arising from questioning or from a pupil request for clarification, and access to portable computers greatly facilitates computer-assisted follow up where appropriate.

While two of the teachers in the study tended to prefer the security of a network provision, having experienced serious problems with the machines which had later to be withdrawn, the majority of the teachers considered that the:

- §.. accessibility of the portables and the immediacy of their availability when a suitable opportunity presented itself;
- §.. continuity from one lesson to the next (with the added bonus of using the machines at home in the intervening period); and
- §.. personal learning environment afforded to each pupil when the need arose (particularly in mathematics and English)

surpassed the constraints of network or stand-alone desktop provision. The number of machines which could be made available for pupils to use in the science laboratory was also very important for some science practicals involving, for example, sensor equipment. All of the teachers appreciated the convenience of being able to tackle IT-related curriculum dimensions in their own rooms when they chose to and also commented on the convenience of having portables for capitalizing on 'spur of the moment' learning opportunities.

'New' Modes of Pupil Contact

A number of the teachers commented upon having to spend much more time going around the class, dealing with pupils enquiries individually and at close proximity rather than as an answer 'across the classroom'. This need arises from pupils' queries which often require the teachers to be directly behind them looking at their screens. This was a new and unwelcome feature of lesson management for a number of the teachers.

Teaching Effort

The combination of having to teach with the portables and having to cope with the hardware and software queries and problems was reported by all of the teachers to leave them feeling drained. Although this reduced considerably as time went on and the use of the portables became more routine, the teachers still considered there was an added intensity to the lesson arising from the effort needed to integrate the portables into the teaching.

Absentees and Pupils without Machines, Disks

On the occasions when machines went 'down' in a lesson or when pupils didn't have machines (having forgotten them or having returned them for repair) the teachers were faced with coordination problems, which drew heavily on their time and effort. The normal problems of enabling absentees to catch up with class work were also found to be compounded, when the work involved portables, as the teachers had to spend time 'at the machine' to direct the absentee pupil's work or to organize the sharing of files and so on, instead of perhaps simply directing that a piece of work should be done. Where the work involved peripherals (an example is the use of sensors in science), the setting up of the specialized equipment added to the diversion of the teacher's time and effort.

'Forgotten' Machines, Disks

In some cases it was felt that the pupils deliberately 'forgot' to bring machines (or disks) either to avoid work or simply to avoid having to carry them. Such instances cause a degree of disruption more than, say, a forgotten book as the sharing of machines and files is not so easily arranged. The incidence of some pupils 'deliberately' forgetting disks and so on, although a tiny minority in the classes observed, did emphasize that the portables did not enthuse all of the pupils all of the time.

Contingency Strategies

The teachers had developed contingency strategies which included having:

- §.. spare machines (if available) ready for replacing broken down machines;
- §.. charging facilities ready to use;
- §.. printing facilities made ready (paper loaded and so on);
- §.. instructions ready for any work not completed and having to be completed at home;
- §.. sharing arrangements;

and in cases where floppy-based machines remain the staple provision:

- §.. a supply of spare disks (with any necessary working files pre-installed).

School and Classroom Organization

Machine Locations

During the project all of the schools at some point allowed the pupils to take the machines home but by the end one school had stopped this because of an unacceptable level of forgotten and uncharged machines. Most of the schools made provision for the pupils to leave the machines in school overnight if they wished but they discouraged this for security reasons. Over the whole project only one machine was stolen and this was taken from the school premises. After an appeal from the principal the machine was returned anonymously. As the project progressed more and more of the pupils chose to leave the machine in school if they didn't have specific work to do at home.

Charging Facilities in School

All of the schools had made some arrangements for charging the machines in school but in one case had stopped allowing the pupils to take their machines home and had also stopped charging in favour of mains use. In this latter case the machines were delivered to the classroom on a trolley and power was provided through wall socket connections. In another school the lack of powerpoints (with only one old-fashioned 5 amp socket) made it an imperative that the pupils charged their machines at home.

Powerpoints and Battery Charging

In some cases the use of small rooms, which in most other respects were satisfactory for the group, were found to be very cramped for portable lessons. It was especially difficult to organize supplementary charging when batteries were spent. The lack of suitable powerpoints in some rooms compounded the difficulties of charging ‘flat’ machines and the ‘trailing leads’ of the battery charging transformers, and of any shared ‘four-gang’ power leads, gave rise to safety concerns.

Furniture

Some types of classroom furniture (eg. one-pupil desks) were found to be unsuitable for portable usage. Small desk-top surfaces made the use of portables, and any attendant paperwork or books, very difficult to manage. Larger four-pupil type tables were found to be more suitable both to manage the various resources and the portables and to enable pupils to engage in cooperative work when that was deemed appropriate.

Lighting

Classroom lighting also presented problems in some circumstances. In bright eg. sun-lit conditions direct light falling on the back-lit screens made them a little uncomfortable to read while low light conditions on the liquid crystal display machines had a similar but more pronounced effect.

Classroom Resources

Some teachers, who had been offered rooms which had better facilities (for portables) than their usual rooms, preferred to accept the inconveniences rather than move from the room where they were most comfortable in their teaching and which offered the necessary resource base for their lessons.

Use of Peripherals

Aside from sensors in science, the only peripherals which were observed to be used, and to be used very heavily, were printers. It was not unusual for these to be in action both throughout a lesson and after it had been completed. No classes were found to have used machine-to-machine downloading but several had transferred files from personal disks to desktop machines. In the main most pupils printed from disk (or left their disks so that their files could be printed from them) but some did connect their machines directly to the printer cables without any reported interface damage problems. The number of printers in the portable classes varied from two to five and the amount of paper used per pupil varied from one page in a science or mathematics lesson to as many as seven pages in an English lesson.

Printing Pupils' Work

Enabling pupils to access printers was a major problem, especially when the printed material was required within a particular lesson. When the material was not needed immediately the problem was reduced but still required the organization and coordination of the printing by the teacher, by technical staff or by the pupils after the lesson. In most cases this meant the use of 'free' time (by the teachers and pupils) before lessons started in the morning, at break and lunch times, during registration periods and after school. The consensus was that printing facilities need to be organized in a manner which does not require the intervention or attendance of the teaching staff, except when the printing is required in the lessons themselves.

Printer Noise

Printer noise was considered to be a major disrupting factor in lessons. Pupils and teachers both needed to raise their voices to be heard and the noise was considered to be an unpleasant environmental factor which militated against good classroom working. In one case, in order to lessen the disturbance, the printer was set up in the corridor. It is likely that printer silencer hoods or relatively quiet ink-jet printers would reduce this problem but none of the schools had adopted these solutions.

Printer Speed

The speed of printing was reported as a major nuisance factor with a particular complaint, for example, being the need for up to five minutes to print out a pupil's graph from Microsoft Works. With perhaps in excess of 30 pupils waiting for print-outs in a mathematics class the situation can become untenable. Some teachers resorted to printing out a small selection of such graphs and then photocopying them for the rest of the class. This, of course, is a software issue and faster printer drivers should be available in the future.

Software

Ease of Use

The teachers expressed concerns about the ease of use, for both the pupils and themselves, of the supplied software and especially the database and spreadsheet applications. Indeed it was been difficult for them to assimilate the processes themselves and then to pass these on to the pupils. In one case a teacher explored the possibility that, with the pupils being so technically literate (about half way through the project), they would not require the step-by-step worksheet approach used hitherto. He provided the instructions verbally for a particular spreadsheet activity, using the MSDOS version of Microsoft Works, but in the end he had to record his dismay (though not his surprise) that the pupils still could not absorb the key sequences needed to carry out the functions. He resigned himself to continuing to develop worksheets and to much verbal repetition of instructions. To some extent this is not an unexpected perception of the use of this Works version and the Apple and Windows versions are considered to be superior in ease of use. The ClarisWorks software on the Apples was found to be reasonably easy to use. It is important to note that the easier a package is to use the less likely technical queries will disrupt lessons.

Variety of Software

The variety of software used in the project included wordprocessors (Microsoft Works, ClarisWorks and Flexiwrite), databases and spreadsheets (Microsoft Works, ClarisWorks). Logo work was facilitated through the use of a specially commissioned package called QLogo and data-logging was supported by the Educational Electronics/NCET Sense and Control package. One teacher used a desktop publishing package, called Newsmaster, very effectively on the Toshiba T1000SEs. Some of the teachers identified software packages they would like to have had for their classes but in the main they were unable to purchase them due to financial constraints. Others complained that they did not know what was available for the machines they had and there was also the complaint in some cases that the software which the school already had, particularly science simulation software, was not compatible with the portable machines. Although the IT literacy of the teachers increased dramatically over the period they remained relatively ignorant of hardware and software compatibility issues and of the sources and procedures for acquiring software.

Primer Guides

There was consensus on the need for carefully designed primer guides covering the common software packages for both teachers and pupils. It was felt that this need was accentuated by the fact that in many cases the pupils (and teachers) would be using them away from sources of technical help, and in particular at home. The provision of effective worksheet-type materials was also considered necessary to reduce the level of support the pupils need when using the software during lessons.

Hardware

Robustness, Durability

All in all the machines proved reasonably robust under the regime of relatively 'rough and tumble' usage by the pupils. Minor problems appeared early including, for example, interface/external port covers coming off and in some cases being lost. A degree more serious but manageable (with various 'sticky-tape' remedies) were the dislodgement of battery cover doors and, in the case of the Apple Powerbooks, tracker ball 'click' buttons. Most machines quickly developed a top-to-bottom mis-matching of the machines' hinged halves (in the form of a slight overlap) but this did not appear to affect the working. Many of the early NB100 machines, however, developed screen hinge cable faults which caused their eventual withdrawal while the Powerbooks also experienced problems associated with their powerline connectors.

Reliability

Four of the schools were initially equipped with a machine which had fundamental reliability problems and which was eventually withdrawn. The teachers involved experienced various degrees of frustration, disappointment, anger and despair at the level of machine problems they had to deal with. In one case, owing to the breakdown of 75% of machines, the activity ceased completely at the end of November 1991 and only recovered in mid-January, 1992 when the machines had been replaced *en masse*. In another case work was suspended from mid-December, 1991 until the arrival of the replacement machines at the start of January, 1992. The diaries of the pupils concerned were particularly graphic: *"I'm starting to think computers are a waste of time because they keep breaking..."* and *"I don't really like the computer because it causes so much hassle..."* The experience for all concerned would suggest that for successful integration the reliability of machines must not be compromised.

Protective Carrier Bags

The incidence of machine breakdown was significantly less for those who had protective covering or bags for them. The primary school, for example, suffered a slower breakdown rate of machines than the two secondary-level schools which were using them to the same intensity and which were also allowing the machines to go home with the pupils. The machines in the primary school were protected by a cover designed and made by the teacher, using a simple fold-over document envelope with a plastic bubble-packaging liner, while the machines in the other two schools were carried unprotected. It was not clear how the protection could have affected the breakdown rate particularly as the main problem centred on the ribbon cable in the hinge connecting the screen to the lower half of the machine's clam-shell. It should be noted that there was no indication of the pupils abusing the machines. Work also continued in the remaining school which had the same machines but in their case the level of usage and consequently the level of breakdown had been relatively light since the beginning of the project.

From approximately January 1992 onwards all of the pupils could avail of some form of carrier protection for their machines. In most cases this was a shoulder bag supplied by the project or the manufacturers while in two schools wooden carrier boxes made by one of the schools' craft departments were available. In one school a decision was taken not to give out the manufacturer's recommended bag as it was felt that it would make the pupils conspicuous going to and coming from school and would therefore make them vulnerable to bullying or other mischief. It should be noted that the pupils did not like the bags or boxes because in their own words they were not *"cool"*!

Portability

The pupils regularly complained about the weight of the machines, especially when they had to carry them in addition to PE kit, musical instruments and so on. The weight of laptops, at approximately 5-7 lbs, remains a considerable disincentive to pupils carrying them around at all times and it is felt that they would need to drop to the level of 1-2 lbs before this situation would be alleviated. The lack of a handle, while not expressly mentioned by the pupils, was clearly an additional factor as pupils could be observed to be uncomfortable, and even a little concerned about losing grip, when they handled them ‘clutch bag’-style. With the considerably lighter WP2 wordprocessor machine this did not appear to be an issue. Some of the teachers felt that while a handle was probably a good idea for moving the laptop from place to place eg. bag to desk, it would not address the problems related to carrying chargers, mains power adaptors or disks. Some kind of carrying bag would still be needed. In the special school the carrier bags were particularly appreciated because they were easily hung over wheelchair handles and so on.

Warranty and Non-warranty Machine Problems

Aside from the inherent problems associated with one of the chosen portables, machines which ‘went down’ fell into two categories: those with warranty supportable faults such as screen distortion, partial loss of screen and so on; and those which had suffered accidental physical screen breakage, breakages in the casing and so on and therefore fell outside of the warranty conditions. The incidence of the latter serious breakages was very low (working out at less than one per school over the project) while less serious but no less disruptive problems such as disks jammed in disk-drives were relatively common. There were a number of instances where disks became corrupt through having been carried in blazer pockets, pencil cases and so on. In some cases the teachers were not sufficiently technically literate and returned machines which were not actually faulty. Examples included machines which were returned with only the batteries flat, machines which failed to read disks which then turned out to be dirty and machines which had been configured to provide a US keyboard layout on starting up.

Supplier Support

The suppliers for the most part displayed a considerable degree of goodwill by fixing non-warranty problems at no charge although it was not always certain that the schools appreciated the distinction and therefore the gesture. As the project went on at least one teacher complained of finding it more difficult to contact the suppliers. The combination of machine ‘breakdown’, the limited free time of teachers and the suppliers’ ‘lack of urgency’ can lead to much frustration as was the case illustrated by the following experience:

> A pupil complained that his password (which the machine allowed him to set) was not working. The teacher tried it without success and decided that the pupil had forgotten the password he put in. The pupil was adamant he had not forgotten but in any case the teacher realized that the only solution was to contact the dealers to find out how to override the password. The dealer said they could not give that information and the teacher must contact the supplier. The teacher telephoned the supplier’s ‘hotline’ and faced several lectures on the need to remember passwords when they are set etc. Eventually after three telephone calls to the hotline he was advised to put his request in writing since, for security reasons, a telephone request could not be attended to. With written details of the serial number and warranty dates he finally received the password override codes and was then able to use the machine. To his surprise he found the password had been correct and that nine keys on the keyboard were actually faulty. These had caused the password to be read incorrectly by the machine (he had been lucky the override code did not involve any of the keys). The whole process took three weeks, a lot of teacher time and one pupil completely without a machine.

Password Protected Hardware

The previous section outlines the difficulties which a password facility can cause if the facility is accessible to the pupils. No reasonable use for the password facility could be found for floppy-based machines and the potential nuisance value may make it undesirable for harddisk machines unless control rests with the teacher.

Insurance

A number of the schools negotiated some form of insurance to cover the incidence of accidental damage to the machines. In some of the ‘maintained’ schools (those retaining a degree of church control) the machines were included in their normal policies arranged by their collective organization while the ‘controlled’ schools (those wholly managed by the local authority) sought individual arrangements with the local authority or commercial insurance groups. As might be expected the choice of having or not having insurance is not a simple one since, on the one hand the premium and on the other a screen breakage, can each cost as much as half the original machine price.

Screen Quality

The back-lit screens were by far the most popular and were considered the most appropriate for classroom use, with the VGA versions (in the RM Notebook 201s) being particularly well received. Liquid crystal display (LCD) screens were roundly criticised as being difficult to read and awkward to set for lighting conditions and angles of incidence.

Power Issues

The machines were all fitted for mains operation and mains charging of the rechargeable batteries. The recommended charging periods varied from 4 to 10 hours while the lifetime of the fully charged batteries was variously quoted as between 2.5 and 4 hours. In practice the batteries discharged in less than two hours in most circumstances although it should be noted that all of the machines, with the exception of the Apple Powerbooks, were floppy -based and therefore most activities would have consumed power relatively quickly as a result of accessing floppy disks. The harddisk machines would consume power at a comparatively slower rate.

Battery Issues

The most common batteries, Nickel-Cadmium (NiCad) rechargeables, suffer from ‘memory’ problems. When a battery is only partly discharged and is then connected to the mains for recharging, the battery does not fully recharge although it gives the appearance of having done so. The battery ‘remembers’ the charge-discharge ratio and each subsequent charge-discharge cycle results in a reduced charge capacity although it never falls below 75% of its true maximum. However, it should be noted that rechargeable batteries have finite life-times and may reduce to 60% of their original capacity after 500 charge-discharge cycles. The manufacturers recommend that batteries should be completely discharged once a month to return them to full capacity. The experience of the project was that the concept of battery ‘memory’ was too subtle for most of the pupils and teachers with the result that the batteries in the machines had varied charging histories and charge levels.

The Apple Powerbook uses a ‘sealed lead acid’ battery which, while not being prone to the same ‘memory’ problems, is generally less robust. For example if left discharged for long periods their maximum capacity may fall to as little as 50% of the original. It is also reckoned that the NiCad batteries have up to four times the lifespan of sealed lead acid types. Both types of batteries represent a significant proportion of the total weight of any portable machine. Advances in battery technology in combination with solid-state memory storage as an alternative to disk drives, will be needed before the desirable power and weight improvements can be made.

Disk Storage

With the exception of the Apple Powerbook 100s which had internal 20 megabyte harddisks fitted as standard, all of the machines had 1.4 megabyte floppy disk drives. These high density disks enabled major software packages such as Microsoft Works to be provided on one disk. Other machines of similar specifications to those used in the project have 720K drives fitted with the consequence that much software which would fit on 1.4MB disks would require two disks, thereby raising the possibility of not being usable or, if usable, then presenting the attendant inconveniences of disk changing and increased power consumption. For optimum usage of available software such as Microsoft Windows, a harddisk is necessary and the teachers in the project took the view that if schools do buy portable computers they should at least provide the teachers with harddisks, if providing them in pupil machines proves unacceptable. If floppy-based machines are to be purchased, the drive specifications should be high density for optimum usage.

Virus Protection

The Apple Powerbook 100s had external floppy-drives which the school concerned opted not to give freely to the pupils. This had the school's desired effect of controlling the incidence of games software usage and also of preventing virus problems. Virus infection on harddisk machines is a significant problem, especially with the amount of games software being exchanged for home computers and the like and so virus protection software should be considered necessary for such machines. Floppy-based machines are much less prone to virus problems and none were detected on the machines in the project.

User Interface - Apple

The Apple Powerbooks had the familiar Apple interface with an in-built trackerball just below the keyboard. Two curved click bars were available above and below the trackerball, to be effected by clicking with the tips of the fingers at the front or with the wrist-hand joint at the back (both having the same effect). This arrangement gave problems arising from hitting the spacebar in place of the front click bar and vice versa. It was suggested that the bars would be more conveniently placed to the right and left of the trackerball for execution using the thumb or little finger respectively. With respect to the software facilities the Apple interface was exactly the same as its desktop equivalents, offering the usual ease of use and cut-and-paste type facilities. In common with other portables the screen pointer suffered ‘ghosting’ effects ie. fading tracks of the pointer as it moves across the screen.

User Interface - IBM Compatibles

The IBM compatibles were all floppy-based machines and therefore unable to provide a Microsoft Windows interface. Software for the machines was therefore wholly keyboard driven and much less easy to use. The teachers commented on the difficulties which they and the pupils had in remembering key combinations in the various systems, and in particular the cut-and-paste routines of the MSDOS version of Microsoft Works. Given a harddisk the Toshiba 8086 processor-based T1000SEs could conceivably run a restricted version of Windows in a CGA graphics mode but attempts to tailor an old version of Windows were not successful. The 80286 processor-based Research Machines NB 200 was shown to be quite satisfactory running Windows 3 from a harddisk.

Memory

Extended memory configurations can considerably enhance performance and power consumption. The common configuration of machines at present is 1 megabyte of random access memory (RAM) and all of the machines in the project had at least 1MB RAM with 2MB in the Apple Powerbooks. In the case of the MSDOS (IBM-compatible) machines, portions of any installed extended memory can be configured to create a ‘silicon disk’ which then acts as another disk drive without, so to speak, the moving parts which consume power in normal disk drives. Using programs and files which are copied into the ‘silicon disk’ from conventional disks is virtually instantaneous and miserly on power consumption, leaving the original copying action and the final saving action (since the silicon disk loses its contents on switching off) as the only necessary disk accesses. It is therefore felt that in selecting machines more than 2 megabytes of RAM is desirable with much more being needed if the proposed software so demands.

Some Conclusions

The PLAIT project covered a variety of issues and gave rise to a series of recommendations and conclusions. Many of these were related to policy issues and addressed such matters as school management perspectives, parents' views and so on. In relation to input of portables to teaching and to the curriculum, and in particular the core trio: English, science and mathematics, the following conclusions would appear to have reasonable consensus.

For English, pupils with their own portable computers can make sustained and purposeful use of wordprocessors and desktop publishing (DTP) software. Most of the learning outcomes in writing can be addressed through the media of wordprocessing and DTP and there are notable benefits to be gained from the use of spell-checking and thesaurus facilities.

For science, pupils with their own portable computers can usefully avail of:

§ wordprocessors and spreadsheets. These lend themselves particularly well to aspects of experimental work - writing up with the former and processing data with the latter;

§ databases software. Useful outlets include the management of collections of data from survey or other field-type work, some of which may also arise from cross-curricular activities;

§ sensor technology. Sensor kits are now readily adaptable to portable computers and the portability of the machines holds out the promise of sensing work 'in the field'.

One-to-one portable ownership does not inhibit group and collaborative working - indeed limited access to peripheral equipment such as sensors is easily compensated for by adopting group work strategies with a smaller number of machines.

For mathematics, pupils with their own portable computers can usefully avail of:

§.. spreadsheets for exploratory and investigatory work, such as comparing simple and compound interest, and also for functional activities such as graph and chart drawing, for solving equations and for carrying out financial feasibility and other calculations;

§ Logo software to explore mathematical relationships in problem solving environments;

§ databases for studying collections of information, applying simple statistical analyses and so on.

The potential for access to IT which portables afford is considered to be particularly beneficial in enabling pupils to engage in mathematics activities in their own time and for longer periods. One-to-one portable ownership is also considered to have a number of major advantages over network provision. It enables work to be carried on after class and it also offers teachers the facility to use the technology on the ‘spur of the moment’ and in their own classroom environment.

The general conclusions of the project derived from the clear observations and evidence of high levels of pupil motivation, harmonious and purposeful learning environments and a greatly accelerated information technology literacy among the pupils and teachers alike. In the latter case it was clear that the convenience and accessibility of the ownership of a portable was a particular factor in raising the teachers’ IT literacy and it seems reasonable to suggest that in order to ensure that teachers are properly equipped to integrate IT fully into their teaching repertoire, portable ownership should be encouraged.

It remains to be seen whether portables will become as common in our pupils’ schoolbags as the now ubiquitous calculator, but there seems little doubt that so long as there is a case for computing in our curriculum then class sets of convenient and personal portables will be more attractive than cumbersome and relatively immobile desktop machines.

References quoted in the text:

Papert, S. 1980. *Mindstorms: Children, computers and powerful ideas.* Basic Books, New York.

Roblyer, M.D. 1985. *Measuring the impact of computers in instruction: a non-technical review of research for educators.* Association for Educational Data Systems, Washington, DC.

SOED 1991a Guidelines for Mathematics 5-14, Scottish Office Education Department, Edinburgh

SOED 1991b Guidelines for English Language 5-14, Scottish Office Education Department, Edinburgh

Further reading:

A limited number of copies of the full summary report of the PLAIT project is available from the National Council for Educational Technology - NCET (London). NCET has also published a report on issues to be considered when purchasing portable computers. Details of the quantitative research findings (on learning outcomes and attitudes) are available from the author at School of Education, Queen's University of Belfast. A brief report on the use of portable computers in Scottish schools is available from the Scottish Council for Educational Technology, Glasgow.

Readers may also wish to refer to the various curriculum documents (programmes of study, non-statutory guidelines and so on) on English, science and mathematics and other subjects as published by the Department for Education and the Welsh Office (available from HMSO), the National Curriculum Council (England and Wales), the Department of Education for Northern Ireland and the Northern Ireland Curriculum Council.